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(54) **Bidirectional optical space switch.**

(57) A bidirectional optical space switch for selectively coupling an input signal to a selected output comprises two arrays of inputs (1, 8), two arrays of outputs (5, 9), polarising beam splitters (2, 4), and a matrix of cells (3) each of which is selectively capable of varying the polarisation state of light passing through it in response to an applied control signal. A first optical system (6) couples each of inputs (1) and a corresponding one of outputs (9) with a corresponding column of cells while a second optical system (7) couples each of inputs (8) and a corresponding one of outputs (5) with a corresponding row of cells. One of inputs (1) is switched to one of outputs (5) by activating the appropriate cell so that it rotates the polarisation of light passing through it by 90°. This also couples one of inputs 8 to one of outputs (9) thereby providing bidirectional switching. Use of combined beam splitters and polarisers (2, 4) provides bidirectionality at substantially no loss of light additional to that lost on discrimination of the polarisation states.

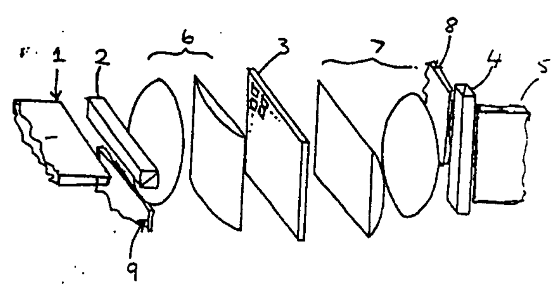

Fig 1

EP 0 277 779 A1

Description

BIDIRECTIONAL OPTICAL SPACE SWITCH

The present invention relates to a bidirectional optical space switch which is capable of use in a centralised switching system for an optical network. A centralised switching system is the simplest active network which is compatible with optical and electronic multiplexing, offers the maximum network size, range, and flexibility and is also compatible with the existing wire-networks.

A paper to entitled "4 × 4 optical - Gate matrix switch" by A. Himeno and M.Kobayashi (Journal of lightwave Technology Vol LT-3 No.2 April '85) discloses an optical gate matrix switch in which optical signals entering each input port I_i of four input ports are distributed by an optical splitter S_i to each of gate elements G_{il} to G_{i4}. When a desired single gate G_{ij} is opened a light signal can pass through the gate to an output port O_j via a combiner C_j, which combines the outputs of all gates G_{1j} to G_{4j}, to an optical receiver. This arrangement permits multiconnections between any input port I_i and any plural output ports O_j to be obtained. Each optical gate G_{ij} is formed by a polarisation rotator placed between its own polariser and crossed analyser to form an on-off optical gate controllable by a driving voltage applied to the polarisation rotator. A disadvantage of this arrangement is that it is uni-directional.

According to the present invention a bi-directional optical space switch comprises:

a first and a second array of inputs for emitting optical signals to be switched;

a first and a second array of outputs for receiving switched optical signals from the first and second array of inputs, respectively;

an active array of cells having first and second sides each cell being selectively capable of varying the polarisation state of light passing through from one side of the cell to the other in response to an applied control signal;

a first optical coupling means for optically coupling the first sides of each of a plurality of groups of cells with a corresponding inputs of the first array of inputs and with a corresponding output of the second array of outputs;

a second optical coupling means for optically coupling the second sides of each of a plurality of groups of cells with a corresponding input of the second array of inputs and with a corresponding output of the second array of outputs;

the first and second optical coupling means including a respective first and second polarising beam splitter each arranged both to polarise light travelling from each input to the array of cells and to direct appropriately polarised light, only, passing through a cell away from the inputs and to the outputs.

The polarising beam splitters may, for example, comprise two right angle prisms having their hypotenuse faces cemented together and sandwiching a dielectric multilayer so that light polarised in the hypotenuse plane is reflected by the film and turned through 90% whereas light polarised transverse to the hypotenuse plane passes straight through the splitter. The use of a polarising beam splitter in the bidirectional switch according to the present invention ensures that there is substantially no loss of light save for that lost on discrimination by its polarisation state since the polarising beam splitters provide both the polarising means and the beam splitters. If a non-polarisation state selective beam splitter were used in series with a separate polariser there would be typically a 50% loss, at both beam splitters leading to a minimum of a 75% power loss through the switch. The present invention therefore provides a particularly effective bi-directional optical switch.

Preferably the active array of cells has the form of a matrix array with the optical coupling means being arranged to connect each input to its respective column, or row, of the matrix array of cells and to couple each row, or column, to its respective output. Preferably the input and output arrays are formed by linear arrays arranged perpendicularly to one another and the optical coupling means are formed by lenses or holograms arranged to couple the light from a particular input to a particular column or row of the array and, correspondingly arranged to couple light from a particular row or column of the array to its respective output.

The active array of cells is preferably formed by an array of liquid crystal devices including devices of the twisted-nematic type. However, other types of liquid crystal devices such as scattering cells may be cascaded with the devices of the twisted nematic type to improve the overall contrast ratio.

The polarising beam splitters are preferably arranged to direct to an output light in a polarisation state opposite to that of light impinging on the active cell from an output so that, it is only when the light passing through the selected cell has its plane of polarisation rotated through 90% that it can pass through the polarising beam splitter downstream from the active cell array and be directed to an output. However, it is also possible to have the polarisating beam splitter arranged to direct to an output light in a polarisation state the same as the light impinging on the active cell array from an input and arrange for all of the active cells except for the selected cell to rotate the plane or polarisation of light passing through them by 90%.

Whilst typically an optical switch according to the present invention is arranged so that each and every input can be selectively coupled to each and every output it is also possible to arrange for the distribution and collection means to provide particular multiple connection and barring schemes. Thus, where it is required that a particular input signal is sent to more than one output destination, it is possible to arrange for the optical means to couple corresponding cells in each group to more than one output or, where it is required for a particular input not to be able to be connected to a particular output,

it is possible to arrange for the optical means not to couple the corresponding cells in some of the groups to a particular output.

The arrays of inputs may be provided by the ends of a number of optical fibre waveguides or, alternatively, by a number of optical devices the outputs of which are modulated by the input signals. Thus, each array of inputs may all be taken from a single optical source which is split, and each split component is modulated in accordance with an input signal or, alternatively, the devices may be formed by a number of independent optical sources each of which is modulated in accordance with an input signal. The arrays of outputs may be formed by the ends of arrays of optical waveguides leading away from the optical space switch or they may be formed by an arrays of photodetectors which detect the light received. Such photodetectors may form part of an optical regenerator which, in turn, generates an output in the form of an optical signal.

In this way the optical space switch may be used as the switching element of an electrical communication system in which the electrical input signals are converted to optical signals at the input to the switch and the reconverted to electrical signals at the output. This can thus avoid the necessity of electrical conduction paths physically connecting each input to each output with switching means connected in series in each path which is required in a conventional electrical cross-bar switch and improves the switch bandwidth. Alternatively, the optical space switch may be used as a switching element for optical signals.

The invention will now be described, by way of example only, with reference to the accompanying drawings, in which-

Figure 1 is a diagrammatic perspective view of a first embodiment of the present invention; and

Figure 2 is a diagrammatic perspective view of a second embodiment of the present invention.

Referring to Figure 1, there is shown a first input array of inputs 1 formed by a ribbon of single mode or multimode optical fibres located in a horizontal plane emits light which is polarised by a polarising beam splitter 2 and impinges upon a liquid crystal matrix array 3. Light passing through the liquid crystal matrix array 3 passes through an analysing polarising beam splitter 4 and thence to a ribbon of single, or multimode output fibres 5, constituting the first array of outputs, located in a generally vertical plane if of the correct polarisation. An optical system 6 comprising a combination of cylindrical and plano-convex lenses 4 is located between the beam splitter 2 and the liquid crystal device 3 to direct the light from each individual fibre in the ribbon 1 to its respective column of the liquid crystal device 3. The lens combination 6 and the polarising beam splitter 2 together constitute the first optical means. A further optical system 7, also comprising a cylindrical and plano-convex lenses, is located between the device 3 and the beam splitter 4. These concentrate light from a row of the matrix 3 to its respective output fibre in the ribbon 5 which together with the second polarising beam splitter 4 constitute the second optical means. The apparatus also includes a second array of input fibres 8 located in the vertical plane and at right angles to the output ribbon 5, and a second array of output fibres 9 located in a vertical plane and generally perpendicular to the input ribbon 1. The liquid crystal device 3 is typically a twisted-nematic liquid crystal device divided into a N $\times$ N matrix, the ribbons 1, 5, 6 and 7 of input and output fibres each containing N fibres.

Thus considering light passing in a first direction through the switch from the input ribbon 1 to the output ribbon 5, the light is first polarised in the polariser beam splitter 2 and any rejected light reflected from the interface in the beam splitter 2 upwards (in the orientation as shown in Figure 1). The optical system 6 spreads the non-rejected light from that particular input fibre over a column of cells of the liquid crystal device 3 which are in a position corresponding to that of the particular fibre in the ribbon. A control signal is applied to one or more of the cells in the column to cause a change in polarisation state of 90 degrees so that light passing through these cells has its direction of polarisation rotated through 90 degrees whereas the light passing through all of the other cells in that column is unaffected. The optical system 7 directs light from the different rows of the liquid crystals device 3 towards the ends of the respective output fibres in the ribbon 5. However, light transmitted through cells which have not changed their polarisation state are deflected by the interface of the beam splitter 4 and only light from those cells which have been rotated through 90 degrees are transmitted through the beam splitter to impinge upon the end faces of the fibres in the ribbon 5.

Light passing in the opposite direction through the switch is introduced via the optical fibres in the ribbon 8. Light of a particular polarisation state is reflected from the interface of the beam splitter 8 and focussed by the optical system 7 onto particular rows of the liquid crystal device 3 corresponding to the location of the optical fibres in the ribbon 8. Those cells in that particular row which have a control signal applied to them to cause a 90 degree rotation of the plane of polarisation for light coming from an input of the first array 1 also will change the polarisation of light passing through it from input of the second array of inputs 8. The optical system 6 collects light from all of the cells and directs it to the polarising beam splitter 2. Light which has not had its direction of polarisation changed passes straight through the beam splitter 2 whilst light which has has its polarisation state changed by 90 degrees is reflected by the inner face of the beam splitter 2 towards the ribbon of output optical fibres 9. The optical system 6 focusses the light from a particular column of the liquid crystal device 3 onto its respective optical fibres in the ribbon 9. Thus, once a particular channel has been established in the optical switch by applying a control signal to one particular cell of the liquid crystal device 3 two corresponding switch connection are made simultaneously, one in each direction through the optical switch.

Where N = 100 a contrast ratio between light which passes through a selected cell of the liquid crystal device 3 and that which does not must be at least 10^4 or 40 dB. With good quality polarising beam splitters 2 and 4 and a twisted-nematic liquid crystal array this is feasible.

Referring now to Fig 2, an optical switch has arrays of inputs 1 and 8, arrays of outputs 5 and 9 and a liquid crystal matrix array of cells 3 as provided in the optical switch of Figure 1. This embodiment differs from that shown in Figure 1 in that polarising beam splitters 10 and 11 are positioned adjacent the matrix array 3. Optical systems 12, 13, 14 and 15 each comprising a combination of cylindrical and plano-convex lenses (illustrated schematically as optical boxes for clarity) direct light to or from the array 3, and to or from the inputs and outputs 1, 5, 8 and 9 respectively via the polariser beam splitters. Optical systems 12, 15 and polarising beam splitter 10, and optical systems 13, 14 and polarising beam splitter, constitute first and second optical means, respectively.

The switch of Figure 2 is functionally equivalent to that of Figure 1 but with polarisation of light from an input by a polarising beam splitter occurring after an optical system has directed the light to be spread over the appropriate row or column of cells, and with the light from the cells being analysed by a polarising beam splitter before passing to an optical system to be applied to an output.

The arrangement of Figure 2 having the imaging optical components of each direction separated allows the output imaging optics of each direction to be optimised without affecting the input optics of the other direction. Input and output optics can therefore be independently optimised. On the other hand, this configuration requires a larger number of imaging devices than the configuration of Figure 1.

Imaging optics utilising lens systems other than the specifically described with reference to Figures 1 or 2, or other methods such as holographic imaging, may be employed which distribute the input signals amongst the cells and convey the resulting signals from the cells to the outputs, however combinations of cylindrical and plano-convex lenses are simple and efficient and have the advantage of being freely available.

It will be appreciated that an optical system according to the present invention can also be used in for uni-directional transmission without modification.

The optical means may include optical waveguides which couple the light emitted from the inputs to the cells and thence from the cells to the outputs. In this case the distribution means may be formed by a number of bundles of optical fibres each bundle being coupled to an input and the fibres of each bundle being coupled, respectively, to individual cells in the group associated with that input. In this case the geometric configuration of the active array of cells may have any convenient form. For example, it may be formed by a linear or even a circular array and may be formed by a single, multi-element component or by a number of discrete components.

Where optical waveguides replace the lens systems 6 and 7 of the embodiment of Figure 1 they have to be polarisation maintaining fibres. Where optical waveguides replace the lens systems 12, 13, 14 and 15 of Figure the ends of the waveguides will ideally be lensed to collimate light existing the waveguides to direct it to a chosen cell of the array 3 through the depth of the beam splitter.

Claims

1. A bi-directional optical space switch comprising -

a first and a second array of inputs for emitting optical signals to be switched;

a first and a second array of outputs for receiving switched optical signals from the first and second array of inputs, respectively;

an active array of cells having first and second sides each cell being selectively capable of varying the polarisation state of light passing through from one side of the cell to the other in response to an applied control signal;

a first optical coupling means for optically coupling the first sides of each of a plurality of groups of cells with a corresponding input of the first array of inputs and with a corresponding output of the second array of outputs;

a second optical coupling means for optically coupling the second sides of each of a plurality of groups of cells with a corresponding input of the second array of inputs and with a corresponding output of the second array of outputs;

the first and second optical coupling means including a respective first and second polarising beam splitter each arranged both to polarise light travelling from an input to the array of cells and to direct appropriately polarised light, only, passing through a cell away from the inputs and to the outputs.

2. An optical space switch as claimed in claim 1 in which each polarising beam splitter is located adjacent the array of cells.

3. An optical space switch as claimed in claim 1 in which each polarising beam splitter is located adjacent an array of inputs and an array of outputs.

4. An optical space switch as claimed in any preceding claim in which the optical means includes optical waveguides to couple the inputs and outputs to the array of cells.

5. An optical space switch as claimed in any preceding claim in which the active array of cells has the form of a matrix array and the optical means is arranged to couple each input to a respective row or column of cells, and to couple each row and column of cells to a respective output.

6. An optical space switch as claimed in claim 5 in which the optical means are formed by lenses.

7. An optical space switch as claimed in claim 6 in which the optical means includes a

spherical lens and a plano-convex lens.

8. An optical space switch as claimed in any preceding claim in which the active array of cells comprises an array of liquid crystal devices of the twisted-nematic type.

9. An optical space switch as claimed in claim 8 in which the twisted-nematic liquid crystal cells are each cascaded with a liquid crystal scattering cell.

10. An optical space switch as claimed in any preceding claim in which the inputs comprise the ends of optical fibre waveguides.

11. An optical space switch as claimed in any one of claims 1 to 9 in which the arrays of inputs are formed by a plurality of optical devices the outputs of which are modulated to provide the optical signals to be switched.

12. An optical space switch as claimed in any preceding claim in which the outputs comprise the ends of optical waveguides.

13. An optical space switch as claimed in any one of claims 1 to 12 in which the outputs comprise photodetectors which detect switched optical signals.

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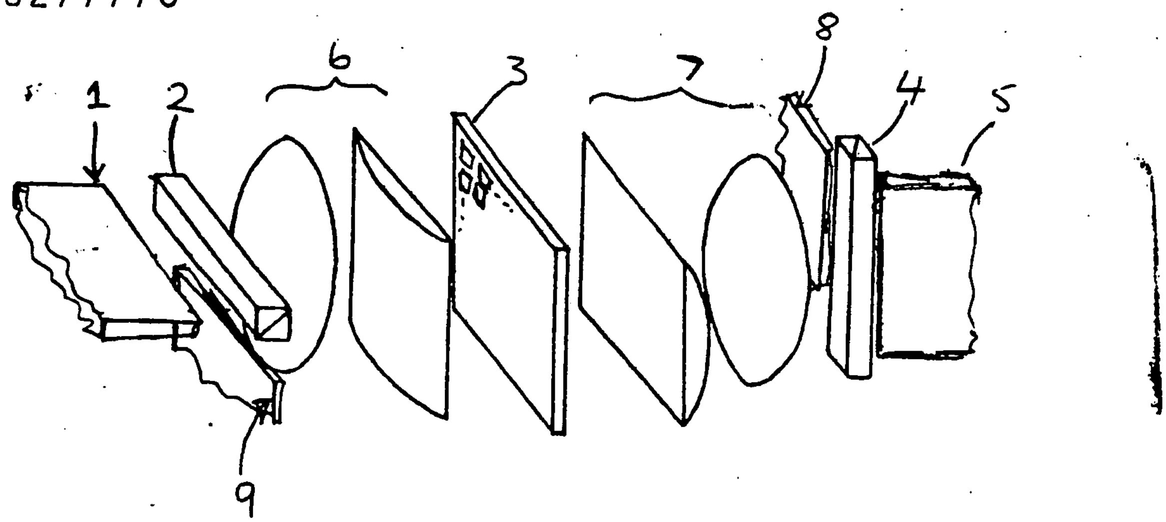

Fig 1

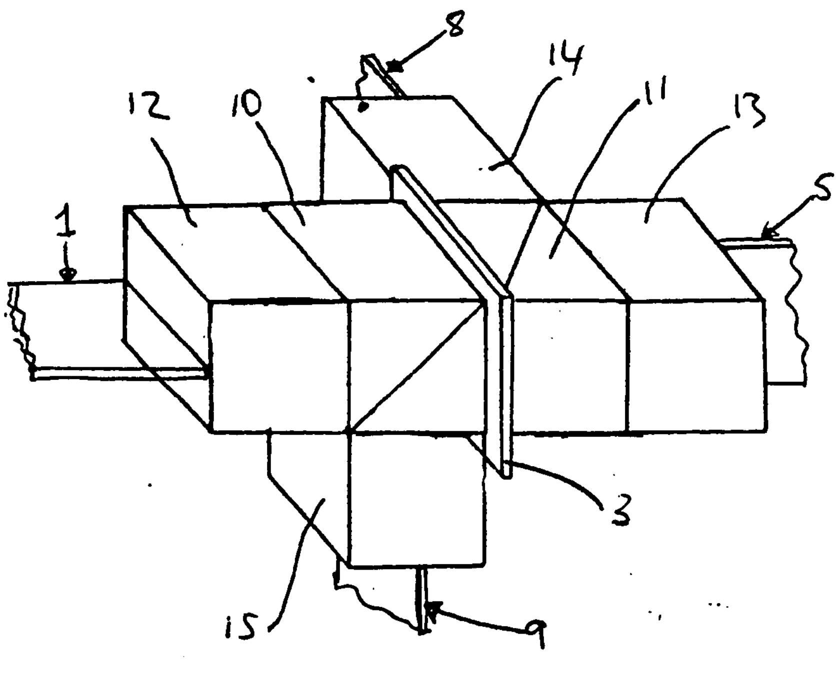

Fig 2

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 88 30 0758

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
D,X	JOURNAL OF LIGHTWAVE TECHNOLOGY, vol. LT-3, no. 2, April 1985, pages 230-235, IEEE; A. HIMENO et al.: "4 x 4 Optical-gate matrix switch" * Page 230, column 1, lines 25-28; paragraphs II,III; figures 1,2,4 *	1-13	H 04 Q 3/52
A	APPLIED OPTICS, vol. 21, no. 8, 15th April 1982, pages 1386-1393; R.A. SOREF: "Electrooptic 4 x 4 matrix switch for multimode fiber-optic systems" * Figures 4-6 *	1-13	
A	EP-A-0 161 683 (NEC CO.) * Abstract; page 19, line 26 - page 21, line 15 *	1	
A	FR-A-2 385 266 (THOMSON-CSF) * Page 6, lines 27-29 *		

TECHNICAL FIELDS SEARCHED (Int. Cl.4)

H 04 Q

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	22-04-1988	GALANTI M.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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A : technological background
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& : member of the same patent family, corresponding document

Optical spac switch.

Patent Number:	EP0277779
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Inventor(s):	HEALEY PETER
Applicant(s)::	BRITISH TELECOMM (GB)
Requested Patent:	JP1502710T
Application Number:	EP19880300758 19880128
Priority Number(s):	GB19870001996 19870129
IPC Classification:	H04Q3/52
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Equivalents:	AU1159588, AU597149, CA1298116, US4923269, WO8805986

Abstract

A bidirectional optical space switch for selectively coupling an input signal to a selected output comprises two arrays of inputs (1, 8), two arrays of outputs (5, 9), polarising beam splitters (2, 4), and a matrix of cells (3) each of which is selectively capable of varying the polarisation state of light passing through it in response to an applied control signal. A first optical system (6) couples each of inputs (1) and a corresponding one of outputs (9) with a corresponding column of cells while a second optical system (7) couples each of inputs (8) and a corresponding one of outputs (5) with a corresponding row of cells. One of inputs (1) is switched to one of outputs (5) by activating the appropriate cell so that it rotates the polarisation of light passing through it by 90 DEG . This also couples one of inputs 8 to one of outputs (9) thereby providing bidirectional switching. Use of combined beam splitters and polarisers (2, 4) provides bidirectionalily at substantially no loss of light additional to that lost on discrimination of the polarisation states.